Mobility in the Small Body Environment: Close Proximity Landing and Surface Dynamics

Completed Technology Project (2016 - 2020)

Project Introduction

Increasingly over the past decade, scientific interest in asteroids and comets has led to the development of mission architectures for both robotic and crewed missions to explore these small primordial bodies. Such exploration helps scientists trace the history and evolution of the solar system and possibly the origin of life on Earth. Furthering NASA's mission to extend human presence into the solar system, missions investigating near Earth asteroids enable exploration of deep space and are also a stepping stone to longer, more extensive missions to Mars and other planetary bodies. Historically, missions to small bodies have been fly-by trajectories, but recent missions have increasingly attempted to interact with the target body. However, previous failures such as the inability of the MINERVA mini-lander to land on Itokawa illustrates that proximity operations about small bodies remains non-trivial. This motivates the development of technological capabilities needed for small body in situ exploration, sample acquisition, and crewed operations, which could be utilized by future missions such as OSIRIS-REx and the Asteroid Redirect Mission. Proposed is the development of models and tools to characterize and utilize the small body environment for close proximity landing and surface operations. First a model of the strength and stability of small body surfaces will be examined. Understanding how the asteroid particle sizes, compositions, and electrical properties combine to form the asteroid's internal strength is necessary to determine how best to interact with the surface. For instance, if an asteroid is only weakly held together, landing on or anchoring to the surface may not be a viable option. This knowledge will in turn affect what types of tools are developed for future crewed and robotic missions of exploration. Next a model of the electrostatic charging process for small bodies will be developed. The surface of asteroids may be very dusty, making the effect of charged dust on spacecraft significant. Understanding and quantifying how asteroids and comets charge needs to be modeled and tested. Asteroid geometries are diverse and unique and are further complicated through material characteristics and non-uniform distribution of conducting and insulating properties. Next, the interaction between the small body environment and spacecraft will be characterized and modeled. This is key to accounting for all the relevant forces and torques acting on the spacecraft when implementing controlled maneuvers. Effects such as the charge of levitating dust particles around the asteroid, in addition to the varying gravitational field around the asteroid, will affect the motion of the spacecraft over time. Finally, sensing and control methods will be implemented. Developing methods and technologies to determine (and potentially directly measure) the strength, stability, and electrical properties of asteroids in real-time will enable spacecraft to more effectively interact with the surface. Taking these measurements and implementing unique controls for the specific environment is a key area of research and will provide insight into how the properties of a small body can be manipulated to improve mission capabilities. It is critical for future space missions to understand and utilize the space environment around small bodies to extend mission capability and

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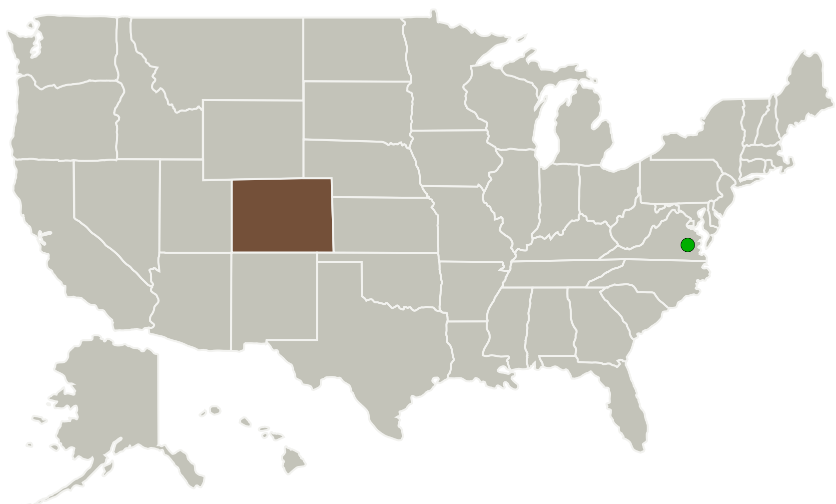
extensibility. Understanding this environment (through modeling and observation) and utilizing this knowledge for maneuverability around and on the asteroid's surface provides versatile control authority for a variety of mission phases ranging from robust orbital maneuvers, approach and landing, new sample return techniques, and overall mission architecture plans. The proposed research explores the synergy of physics and engineering to both better understand and utilize the space environment around small bodies to enhance exploration by both robotic and crewed missions.

Anticipated Benefits

The proposed research explores the synergy of physics and engineering to both better understand and utilize the space environment around small bodies to enhance exploration by both robotic and crewed missions.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Colorado Boulder	Lead Organization	Academia	Boulder, Colorado
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Colorado Boulder

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Daniel Scheeres

Co-Investigator:

Kristin D Nichols

Space Technology Research Grants

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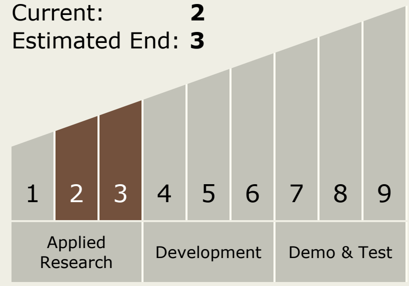
Primary U.S. Work Locations
Colorado

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.4 Vehicle Systems
    └ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Others Inside the Solar System